Marine Fish – Desktop Review and Study Design

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In May 2016 the Special Minister of State asked Infrastructure Victoria to provide advice on the future capacity of Victoria's commercial ports. Specifically, the Minister has asked for advice on when the need for a second container port is likely to arise and which variables may alter this timeline. The Minister has also asked for advice on where a second container port would ideally be located and under what conditions, including the suitability of, and barriers to investing in, sites at the Port of Hastings and the Bay West location.

In undertaking this task, Infrastructure Victoria reviewed work that was completed as part of the Port of Hastings development project before it was cancelled in 2014. This document forms part of the initial work undertaken for the proposed port development at Hastings. Infrastructure Victoria considers that much of the previous Hastings work, although preliminary in nature, is relevant and suitable for informing a strategic assessment. Therefore, Infrastructure Victoria has made the reports previously commissioned for the development project part of the evidence base on which Infrastructure Victoria will use in providing the Minister with advice.

The opinions, conclusions and any recommendations in this document are based on conditions encountered and information reviewed at the date of preparation of the document and for the purposes of the Port of Hastings Development Project.

Infrastructure Victoria and its consultants have used the information contained in these reports as an input but have not wholly relied on all the information presented in these reports.

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1. Introduction

1.1 Context

1.1.1 Project overview

The Victorian Government has identified the Port of Hastings as a key area for port expansion. An expanded Port of Hastings will increase capacity and competition in the container ports sector servicing Melbourne and Victoria helping to manage the expected growth in container trade.

The Port of Hastings Development Authority (the Authority) and its board were established in January 2012 under the *Transport Integration Act 2010*. The primary objectives of the Authority are to:

- manage and operate the Port of Hastings; and
- facilitate the development of the Port of Hastings as a viable alternative to the Port of Melbourne as a container port to increase capacity and competition in the container ports sector to accommodate future growth in trade, consistent with the vision statement and the transport system objectives.

Over the next three to four years, the Authority will be working to develop a business case for an expanded Port of Hastings and undertake comprehensive environmental assessment. This business case will include:

- preferred project design/scope (including transport connections)
- necessary environmental approvals (including impact assessment)
- preferred governance and delivery strategy

In May 2014, the Port of Hastings Development Project was declared a 'Major Transport Project' under the *Major Transport Project Facilitation Act 2009* (MTPF Act).

In July 2014, the then Minister for Ports, Mr David Hodgett, formally appointed the Authority as the Project Proponent under the MTPF Act.

1.1.2 Environmental and social studies

The overall design methodology for the Project involves an iterative design process which has commenced and will continue for around two years. The design process will cycle and re-cycle the evolving design through an evaluation process that allows design options to be tested and evaluated against economic, environmental, social and other objectives and associated criteria. Performance requirements will be developed as an integral part of the design process to clearly define the environmental and social outcomes that the Project must achieve in its implementation phases. The preliminary design will demonstrate the way in which the Authority considers the Project could be developed so as to achieve the performance requirements.

Environmental and social studies are required for the Project to inform the design development process and to assess the Project in accordance with the Approvals Strategy previously adopted by the Authority. An overview of the framework for the environmental and social studies and their relationship with the design process is shown in Figure 1.

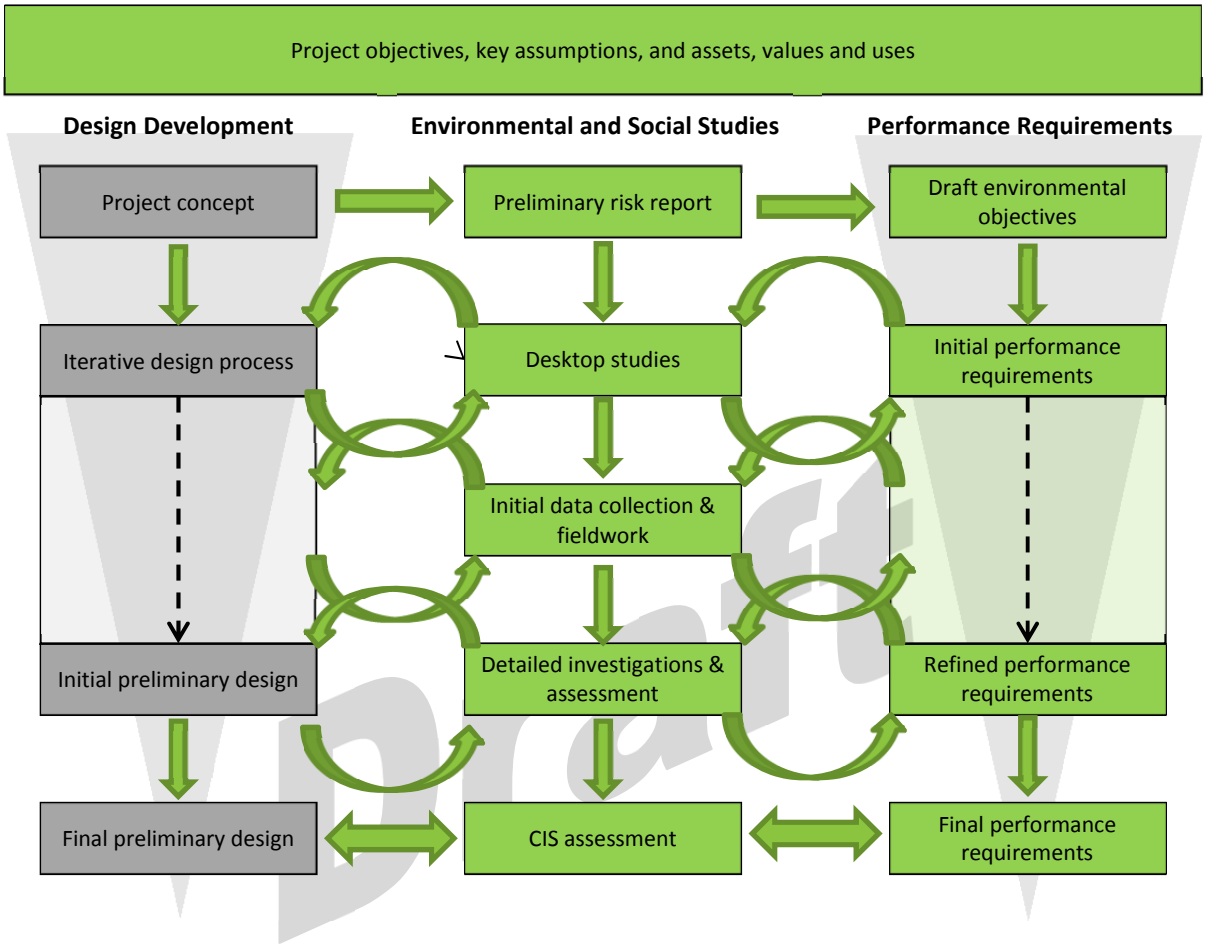

Figure 1. Framework for environmental and social studies

As shown in Figure 1, a stepwise approach is being employed to implement the environmental and social studies for the Project. This reflects both the iterative relationship between the studies and the design development process and their ultimate purpose of informing assessment under the MTPF Act and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The key steps in the implementation of the environmental and social studies are:

- Undertake an initial assessment of need using an issues screening process to identify priorities for studies
- Initiate environmental and social investigations required to support the design development process
- Undertake desktop reviews to complete the assessment of the adequacy of existing information and confirm methodology for any further existing conditions investigations, including field work (where required)

- At the relevant stage of project definition and taking into account emerging performance requirements, undertake field and other investigations to characterise existing conditions
- Following the issue of the preliminary design, undertake risk and impact assessments to support preparation of the CIS.

1.2 Purpose and Scope

The purpose of this report is to present a desktop review of the adequacy of existing information and confirm methodology for any further existing conditions investigations, including field work (where required) for marine fish.

The scope of this report includes:

- Identifying the key questions to be addressed by a marine fish baseline study in support of investigations being completed for the Project
- Review of existing background information and historical data to identify its suitability to define marine fish existing conditions in support of design decision making, impact assessment, identification of relevant management and mitigation measures and development of performance requirements, and approvals requirements
- Identifying gaps in existing data or information which should be addressed to adequately inform design decisions, impact assessment, performance requirements and approvals
- Defining a marine fish study method to address any identified information requirements.

1.3 Limitations

The contents of this document reflect Melbourne University Commercial's current position on the subject matter of this document. It is provided for discussion or information purposes and is intended to be a guide only. The contents of this document should not be relied upon as representing Melbourne University Commercial's final position on the subject matter, except where stated otherwise. Any views expressed by Melbourne University Commercial in this document may change as a consequence of Melbourne University Commercial finalising formal technical studies or specifications, or legislative, or procedure and regulatory developments. Any figures provided are indicative only, are subject to change and are dependent upon a number of factors.

2. Key questions

2.1 Marine fish overview

Western Port is home to a diverse and abundant array of fish species, primarily due to the extent and diversity of habitats available. The bay is highly productive in terms of small fish species; both bottom living species associated with habitat such as seagrass (Edgar and Shaw 1995a), and small pelagic fish that school in large numbers (Hoedt *et al.* 1995). These small fish are important for ecosystem function in terms of providing food for higher order predators such as larger fish (Hoedt and Dimmlich 1994), seabirds and marine mammals.

Western Port is also home to a number of fish and shark species of conservation significance. Listed fish species include the Australian Grayling, Syngnathidae (pipefish and seahorses), the Pale Mangrove Goby and Southern Bluefin Tuna. The only Victorian records of one species (the pale mangrove goby) come from this bay (Hindell and Jenkins 2004, 2005). Listed shark species include the School Shark, Short-fin Mako Shark, Porbeagle Shark and Great White Shark.

Western Port is a key breeding area for some species such as Elephant Fish (Braccini *et al.* 2008), School Shark, (Stevens and West 1997) and Australian Anchovy (Hoedt and Dimmlich 1995), and a nursery area for other species such as King George Whiting, Yellow-eye Mullet, and Australian Salmon (Robertson 1978, 1980; Edgar and Shaw 1995a). Although the commercial fishery in Western Port has declined in recent years (DPI 2010), there is an increasingly important recreational fishery of high economic value for species such as King George Whiting and Snapper (Ryan *et al.* 2009).

Fish populations in Western Port are highly dynamic, and show strong responses to changes to habitat characteristics and water quality (MacDonald 1992; Jenkins *et al.* 1993). Therefore, careful management of the Project is important so as to not impact the ongoing biodiversity and sustainability of the fish fauna of Western Port (Jenkins 2011).

Fish are considered to be a critical environmental component within the ecological character of Western Port, based on diverse fish assemblages including commercially significant species, in relation to the Ramsar listing of Western Port in 1982 (Kellogg Brown & Root 2010). Fish have strong linkages to other components and processes such as providing food for water birds and marine mammals (ecosystem energy transfer), and supporting commercial and recreational fishing (Kellogg Brown & Root 2010). Fish are also linked to seagrass beds that provide an important nursery function for juveniles of a number of fish species (Kellogg Brown & Root 2010).

2.2 Key questions to be addressed by study

Development of key questions has been informed by the Western Port ecological character description which identifies marine fish as a critical ecosystem component and impact pathways that define the potential impact of the development on marine fish.

Extensive impact pathways have been developed to identify the activities associated with the port design, construction and operation that have the potential to impact ecological values in Western Port and surrounds.

Impact pathways that could result from the Project have indicated that there are a number of pathways with the potential to affect fish. These include both direct impacts where the footprint of the Project leads to direct habitat loss or removal of fish, and indirect impacts where pathways such as increased turbidity from dredging affects light for seagrass that provides critical habitat for fish. We have derived a key question in relation to each identified pathway that will provide a focus for studies into how Project design influences potential impacts on fish.

Impact pathways relevant to fish include:

- Direct entrainment and habitat loss from the project footprint (e.g. from dredging)
- Suspended sediment and turbidity direct effects (e.g. clogging, behaviour)
- Turbidity indirect affect through habitat loss (e.g. seagrass)
- Aquatic noise and vibration
- Water current changes affecting larval dispersal and recruitment

Key questions in relation to pathways:

- What fish are in the area?
    - Listed
    - Recreational and commercial
    - Ecological
- What is their vulnerability to these pathways (threshold of tolerance and capacity to recover)?
- What are their habitat preferences?
- Does the relationship between fish and habitat vary with location?
- What is their seasonal occurrence (feeds into work schedule)?
- What is the interannual variation (i.e. ‘natural variability’)

Key questions in relation to Ramsar:

- What were the characteristics of the Western Port fish fauna in 1982?
- How has the fish fauna changed from the 1982 baseline to the present?
- What is an acceptable baseline for the impact assessment?

3. Information Requirements

3.1 Previous studies

Table 1. Summary of relevant previous studies on marine fish in Western Port presenting an annotated bibliography noting the scope of previous studies, relevance to this project, limitations for this project.

Study	Scope	Relevance	Limitations
Shapiro (1975)	As part of the original Western Port Environmental Study, fish were sampled with demersal otter trawls and a 182 m beach seine. Sites were predominantly in the southern half of Western Port and particular habitats were not targeted other than having a "hard and flat substratum". Aggregate indices such as total biomass and cumulative diversity were reported but not data on species composition or individual species abundances or biomass.	**Low** Sites generally not in potential impact area of the project	Sites not habitat specific No data on individual species
Robertson (1977) (1978) (1980) (1982) (1984) Robertson and Klumpp (1983)	PhD study carried out at Crib Point (Woolleys Beach) as part of the Western Port Environmental Study. The sampling was conducted on an intertidal mud flat with patches of *Zostera*. Samples were collected with either a large (50 x 1 m, 1.27 cm mesh) or small (10 x 1.5 m, 1 mm mesh) seine net at approximately 7-weekly intervals during the period October 1974-February 1976. Information on fish community structure and also seasonal recruitment patterns of important species, e.g. King George whiting, Australian salmon. Dietary analysis based on gut contents of abundant species.	**Medium-High** Study site within potential impact area of project Temporal sampling for seasonal comparisons and patterns of recruitment	Sampling not habitat specific for seagrass versus mud Only one site sampled so no information on spatial variation Intertidal only No inter-annual comparison
Howard and Koehn (1985)	Syngnathid species sampled with a beam trawl on 13 occasions from December 1977 to November 1978 in subtidal seagrass at a	**Medium** Temporal sampling for seasonal	Only one site sampled so no information on spatial variation

Study	Scope	Relevance	Limitations
	site near Rhyll. Diet information based on gut contents analysis. Laboratory observations of behaviour.	patterns of reproduction and recruitment Sampling site not in the potential impact area of the project	No inter-annual comparison
Edgar *et al.* (1993); Edgar and Shaw (1995a) (1995b)	Survey of fish in seagrass, unvegetated intertidal flat and channel habitat was undertaken at sites at Tooradin, Peck Point (French Island) and Rhyll, with additional sampling at Cowes Bank and Loelia Shoal (Rhyll Basin). Sampling was conducted with a seine net (15 x 3 m, 1 mm mesh) and gillnets (50 x 3 m, 64 and 108 mm mesh panels). Sampling was quarterly between August 1989 and November 1990 (sampling period varied depending on location). The diet of fish collected was examined using stomach content analysis.	**Medium-High** Documented fish assemblages by habitat Estimated seasonal and habitat differences in fish abundance and production Characterised trophic pathways for different fish species	Study sites not within potential impact area of the project and are unlikely to provide a good proxy for the Port development area. Sampled specific habitats but details (habitat depth etc.) lacking. No inter-annual comparison
MacDonald (1992); Jenkins *et al.* (1993)	Analysis of time-series of commercial catches in relation to the timing of major seagrass (*Zostera*) loss in the 1970s. Catch declines after seagrass loss were significant for species known to associate with seagrass habitat. The decline in the King George whiting catch did not occur in Port Phillip or Corner Inlet.	**High** The data gives an indication of the potential effects of seagrass loss, and the species most likely to decline	Catch data did not consider the effect of fishing effort
Hoedt and Dimmlich (1994);	Sampled pelagic fish (mainly Australian salmon) along a 63 km transect conducted monthly from May 1992 to April 2004. The transect ran in a loop in the south-west of the bay as far north as	**High** Most significant data available on pelagic fish including eggs	Spatial coverage was southern

Study	Scope	Relevance	Limitations
(1995); Hoedt *et al.* (1995)	Hastings. Diet of Australian Salmon was studied based on gut content analysis. Plankton sampling (300 micron mesh) was conducted from May 1992 to January 1994 to collect eggs and larvae of pilchard and anchovy. Sampling sites were mainly in the southern part of the bay and off the coast but three sites were in the Lower North Arm as far north as Hastings.	and larvae	Western Port only No inter-annual comparison
(Jenkins *et al.* 2000)	Post-larval King George Whiting were collected in spring 1995 from sites at Crib Point, Corinella and Rhyll. Samples were collected from *Zostera* seagrass in the shallow sub-tidal zone with a 10 x 2 m, 1 mm mesh seine net. Samples were not quantitative but rather were aimed at collecting specimens for otolith analysis.	**Low** Samples were collected within the potential impact zone of the project (Crib Point) and only confirmed the presence of post larvae in the area	Samples were not quantitative and therefore do not provide information on spatial pattern of settlement
Longmore et al (2002)	Stable isotope study of the key plant habitats supporting the food chain to important commercial fish. Fish were collected by beach seining, trawling in deeper waters, gill and fyke netting in mangroves, or purchased from professional fishers. Samples were collected from 33 sites over two years (1999-2001), comprising six main habitat types. These included sandy beach, mangrove, saltmarsh, mud flat, seagrass and tidal channel rubble. Analyses were completed on 1128 samples collected from 21 species of plants, 16 species of commercial fish and 27 species of potential prey.	**Medium – High** Samples were collected throughout Western Port including the area of potential project impact Variation with area, season and size was examined	Used literature values for isotope signatures of microphytobenthos and phytoplankton Difficult to get unique isotopic signatures for different plants (used mixing models)

Study	Scope	Relevance	Limitations
Hindell *et al.* (2004); Hindell and Jenkins (2004) (2005)	Survey of fish at the mangrove fringe and adjacent mudflat at sites near Hastings, Warneet and Newhaven. Sampling was conducted with seine (10 x 2m, 1 mm mesh), gill net (1.5 x 35m, multi-panel mesh) and fyke net (10 m wings, 6 mm mesh). Sampling was quarterly between January 2002 and November 2002. Samples of fish and plants were also collected for stable isotope analysis of trophic relationships from the same sites from June 2003 - March 2004. Sampling was conducted from October 2003 to January 2004 with a pop-net (5 x 5 m) within mangroves, at the mangrove edge, and on unvegetated mud-flat at Woolleys beach, near Crib Point. A broad-scale survey of fish in mangroves was done using pop-nets between May and September 2004. Three sites each were sampled from the western (Woolleys Beach, Jacks Beach, Hastings), northern (Warneet, Blind Bight, Tooradin) and southern (Churchill Island, Rhyll, Rhyll Inlet) regions of the bay. Samples were taken from within and at the edge of the forest. Seagrass beds were sampled at 3 sites in the west (Woolleys Beach, 2 in Hastings Bight) and 3 sites in the north of Western Port (between Warneet and Tooradin), as well as one site at Rhyll on Phillip Island, in winter 2004. The beds of *Zostera* were located near the edge of channels in the shallow subtidal zone. Samples were collected with a seine net (10 x 2.5 m, 1 mm mesh). Artificial seagrass units were also sampled in the upper and lower intertidal zone at Woolleys Beach.	**High** Fairly extensive sampling of mangroves for fish, including in the potential impact area of the project Sampling was targeted to specific habitats Sampling of shallow subtidal seagrass in the potential impact area of the project Fish abundance and assemblage data for mangroves, intertidal unvegetated mud and sub-tidal seagrass	Broad-scale sampling of mangroves with pop-nets and seagrass was conducted in winter only Broad-scale sampling of seagrass was conducted in winter only No inter-annual comparison

Study	Scope	Relevance	Limitations
Hamer and Jenkins (2004).	Sampled for juvenile snapper with a beam trawl in February and March from 2000 to 2003. Six areas were sampled (5 samples per area) including two in the Lower North Arm, north and south of Hastings. Depths sampled ranged from 2 – 19 m.	**Low-Medium** Intensive sampling showed very few snapper recruits in Western Port	Study focussed on snapper, no information on other species No sampling of specific habitats
Crook *et al.* (2006)	Adult Australian grayling were collected from the Bunyip River between April and July 1998 by *ad hoc* netting and electrofishing. Microchemistry analysis was conducted on otoliths to determine if juveniles underwent a period of marine residence.	**Medium – High** Information on the movement patterns of an EPBC listed species	Small sample size (n=5) Restricted to one River system in Western Port
Braccini *et al.* (2008)	Used creel survey and charter boat log book data to estimate catch, fishing effort and catch rates of Elephant Fish in Western Port. Information on areas most fish are caught as well as reproductive state and estimated age structure.	**Medium** Information on the biology and population trend of an important recreational fishing species	Limited fishery independent sampling
Warry and Reich (2010)	A fish sampling program in seven estuaries entering Western Port (Bass, Bunyip, Cardinia, Merricks, Warringine and Watsons) was instituted as part of the development of an Index of Estuarine Condition. Samples were from lower, middle and upper regions. Sampling was mainly with fyke nets and gill nets but seine nets and mini otter trawl were also used opportunistically. Sampling was conducted from February to April. Fish and plant samples were collected for stable isotope analysis of trophic pathways and otoliths were extracted for age and growth analysis. Physico-	**Medium-High** Broad survey of fish in the estuarine habitats of Western Port Includes information on listed and recreational fishing species	Only one season sampled (a further sampling in spring was planned) No inter-annual comparison

Study	Scope	Relevance	Limitations
	chemical measurements were taken in the estuaries (Warry and Reich 2010).		
Koster and Dawson (2010) Crook *et al.* (2006)	Samples to detect Australian grayling spawning in the Bunyip River were collected approximately fortnightly between March and July 2008 and 2009. Samples were collected from the mid-lower reaches using a drift net (0.5 m diam., 500 micron mesh). Eggs and larvae were identified using genetic techniques.	**High** Information on the reproductive biology of an EPBC listed species Includes inter-annual comparison	Restricted to one River system
Kemp (2010)	Sampling of subtidal channels and embayment plains with a mini otter trawl (3.9 m head rope, 5 mm mesh liner) was undertaken as part of a PhD thesis on the biology of red cod, *Pseudophycis bachus.* Sampling was from October 2002 to March 2004. A large number of sites were sampled around the bay in depths ranging from 3.2 to 16 m. Sites included Hastings, Hastings South, Hastings North and Middle Spit in the Project zone. Apart from quantitative data on a small number of red cod, the data consists of a list of prominent fish species in each trawl, as well as a note of substrate type.	**Medium** One of the only sources of information on fish in the deeper channels and embayment plains, covering sedimentary, algal and invertebrate (e.g. bryozoan) isolates	Data qualitative only including an incomplete species list from each trawl
Kent *et al.* (2013)	Fish egg and larval samples were collected near the coast off Wonthaggi and also from 3 sites within Western Port (eastern entrance, Rhyll basin, and north of Phillip Island). Samples were collected monthly from September 2007 to November 2008 with a 0.8 m diameter, 500 micron mesh plankton net. Two samples were taken at each site, one near the surface and the other near the	**Medium** Provides information on the composition of fish eggs and larvae from the south-eastern area of Western Port	Limited coverage, only three sites sampled within Western Port Sampling restricted to the south-eastern areas of Western

Study	Scope	Relevance	Limitations
	substrate.	Information on seasonal patterns	Port No interannual comparison
Jenkins *et al.* (2013)	Sampling to determine relationships between fish and habitats other than *Zostera* seagrass. Underwater stereo video was used to sample *Amphibolis* seagrass and reef/algal habitat in the Western Entrance area in April-May and October-November 2012. Sites ranged from 2.5 to 7 m depth. Stereo video was also used to sample rhodolith beds in the eastern entrance in November 2012 and April 2013. Sites ranged from 1.5 to 5 m depth. A mini otter trawl (3.9 m head rope, 5 mm mesh liner) was used to sample *Caulerpa* algal habitats near Coronet Bay and Loelia Shoal in the Rhyll segment, as well as unvegetated mud with invertebrate/*Caulerpa* isolates in the Lower North Arm, north of Hastings. Sites ranged from 4 to 7 m depth. Sampling was conducted in October November 2012 and May 2013. Additional sampling with the mini otter trawl was conducted on one occasion (May 2013) in a large *Zostera* seagrass bed north of Hastings (immediately inshore of the mud/isolate site in 3.5 to 4.5 m depth).	**High** Information on the ability of fish in *Zostera* seagrass to utilise alternative habitats Includes information on listed and commercial - recreational fishing species Some sites in the potential impact area of the project including sampling on one occasion of deeper *Zostera* habitat	Two seasons sampled only so full seasonal comparison not possible Deeper *Zostera* seagrass north of Hastings only sampled once No inter-annual comparison

Study	Scope	Relevance	Limitations
Jenkins (current)	Analysis of 15 years (1998 -1013) of Recreational fishing boat-ramp survey data. Surveys were conducted from approximately November to May each year by roving interviewers moving around the major boat ramps in Western Port. Analysis includes trends in catch rate (an index of abundance) of important species over time and in space based on a grid of catch cells. Length measurements of retained fish are also taken.	**High** Catch rate data over time gives an index of interannual variability in abundance and recruitment of important species such as snapper and King George whiting Catch rates can also be linked back geographically to important habitats such as seagrass.	Accuracy of the results depends on the capability of the interviewer and the reliability of the interviewee Data, such as details of fish released, that relies on interviewee memory would be considered qualitative rather than quantitative

3.2 Information requirements

Table 2. Summary of key questions, existing information and information requirements for marine fish existing conditions assessment. (*Includes threshold of tolerance and capacity to recover)

Key Question	Existing information	Information requirements
What are the fish in the area (listed, recreational and commercial, ecological)?	This question is covered to some by existing studies at the scale of Western Port. A number of existing studies, however, did not include sites in the potential impact area of the project. Existing studies also lacked sampling for deeper subtidal seagrass, that is known to have different fish assemblages to shallow seagrass (Hutchinson *et al.* 2014).	The expansive area of seagrass between Hastings and Yaringa (1 to 5 m depth) has only been sampled on one occasion and subtidal beds associated with Middle Spit have not been sampled. Further sampling to characterise the fish assemblage in these areas is recommended. In particular, sampling is needed from deeper, subtidal seagrass habitat for which there is little existing information.
What is the vulnerability of fish to direct entrainment and habitat loss from the project footprint?*	Information on the distribution and habitat associations of fish from existing studies will inform this question. Trends in commercial fish catches following seagrass loss in the 1970s gives information on species most likely affected.	Can be answered to some extent with existing information. Additional information on fish in deeper seagrass habitats, and also fish distribution and abundance in the area of the project footprint is recommended to improve confidence in the assessment.
What is the vulnerability of fish to suspended sediment and turbidity direct effects (e.g. clogging, behaviour)?*	No existing information on this for Western Port and generally poorly understood from other systems. Assessment would depend on studies elsewhere, but these are generally not fish from temperate seagrass dominated areas.	This is a key pathway affecting fish for which there is little information. It is recommended studies on direct turbidity effects on key species (e.g. syngnathids) in Western Port be conducted. Studies could be laboratory and/or field (taking advantage of natural turbidity gradients).

Key Question	Existing information	Information requirements
What is the vulnerability of fish to the indirect effect of turbidity through habitat loss (e.g. seagrass)?*	Effects of total habitat loss can be predicted to some extent based on existing information on distribution and abundance. Where habitat loss is partial (i.e. reduced seagrass density), the thresholds are poorly known with a small amount of work available from other systems. Some information available for Port Phillip Bay (Jenkins *et al.* 2012). Seagrass loss in the 1970s was through a different mechanism (shallow rather deep seagrass was most affected) so may not be strongly relevant to this pathway. There is a lack of information on fish in Western Port from deeper seagrass that would be most affected by increased turbidity (Some information for winter only in Hindell *et al.* (2004) and one sampling occasion in Jenkins *et al.* (2013)). Work in Port Phillip Bay has shown that fish assemblages in deeper seagrass are different to shallow seagrass (Hutchinson *et al.* 2014).	More information is required on fish assemblages in deeper seagrass in Western Port. Deeper seagrass is the most vulnerable to the effects of decreased light through increased turbidity. One of the largest areas of deep seagrass in Western Port is between Hastings and Yaringa in the potential impact zone of the project. Significant areas of deeper subtidal seagrass are also associated with Middle Spit and are likely to be affected by turbidity. Existing fish studies in Western Port generally don't include information on seagrass characteristics at sampling sites that could be used to assess thresholds of seagrass density in relation to fish abundance/biomass. It is recommended that this be addressed in the proposed program by coordinating fish and seagrass sampling.
What is the vulnerability of fish to the effect of aquatic noise?*	No existing information for fish in Western Port. Physiological effects reasonably well studied for fish elsewhere including Australian snapper, behavioural effects less well known.	More information on effects on local species in Western Port would be desirable but a reasonable assessment can be made based on information from elsewhere.
What is the vulnerability of fish to current changes affecting larval dispersal and recruitment*	The only existing information on fish eggs and larvae in Western Port is for anchovy and pilchard from sites in the southern part of the bay (Hoedt and Dimmlich 1995), and limited sampling from the south eastern	Sampling of fish eggs and larvae in the middle to northern areas of Western Port would provide additional information on fish spawning and

Key Question	Existing information	Information requirements
	area of the bay covering all taxa (Kent *et al.* 2013). There is no existing information on spatial patterns of settlement of important species (e.g. King George whiting). The study of Robertson (1977), and later ad hoc sampling, indicates that the Crib Point area has significant settlement of King George whiting post-larvae.	potential larval dispersal. Sampling of post-settlement stages would provide information on the spatial pattern of dispersal and settlement of important species.
What are their habitat preferences?	There is a significant amount of existing information on fish associations with seagrass, *Zostera*, mangroves, and unvegetated mud/sand habitats. Recent work (Jenkins *et al.* 2013) has broadened this knowledge to include association with seagrass, *Amphibolis*, algae, *Caulerpa*, and rhodolith beds. Single sites were also sampled for deeper reef/algae, mud with invertebrate isolates and *Zostera* (one occasion only).	Data is still lacking on fish associations with a number of habitats. Deeper areas (ie channels, sedimentary plains) have large invertebrate isolates (mainly bryozoa) but importance as fish habitat is unclear. Associations with reef habitat in the middle to northern sections of the bay are unknown (e.g. Crawfish Rock). Deeper *Zostera* (3-5 m depth) has only been sampled on one occasion.
Does the relationship between fish and habitat vary with location?	Fish assemblages in habitats such as seagrass can vary with the location of the seagrass bed depending on factors such as proximity to currents delivering larvae, wave exposure etc. Some studies have sampled multiple sites so that geographic variation can be assessed to some extent. A number of these studies did not include sites in the potential impact area of the project. An exception was the study by Hindell *et al.* (2004) for mangroves, unvegetated habitat and	The study of seagrass including multiple sites by Hindell *et al.* (2004) that included the project area was only conducted in late autumn/winter. Seasonal sampling of seagrass at multiple sites including the project area is recommended. No study has included sites in the extensive seagrass bed between Hastings and Yaringa or in beds associated with Middle Spit in a broad scale survey

Key Question	Existing information	Information requirements
	seagrass.	comparing fish in different locations of seagrass beds. Sampling of these sites in a broad spatial survey is recommended.
What is their seasonal occurrence (feeds into work schedule)?	Reasonably good information on seasonal changes in fish assemblages associated with mangroves and unvegetated habitat (Hindell and Jenkins 2004) and intertidal seagrass and unvegetated habitat (Robertson 1978; Edgar and Shaw 1995a). Seasonal sampling of other habitats in Jenkins *et al.* (2013) was only in spring and autumn so was incomplete (and deeper *Zostera* habitat north of Hastings was only sampled in autumn).	Seasonal sampling in previous studies has only been conducted over 1 year so the generality of the results on seasonal changes is open to question. No seasonal sampling has been undertaken in subtidal seagrass in the potential impact area of the project. Seasonal sampling in subtidal seagrass is recommended.
What is the interannual variation (i.e. 'natural variability')	Information on interannual variability in fish populations of commercial and recreational importance can be inferred from catch rates derived from commercial (logbook) and recreational (boat ramp survey and diary angler) fishing data. There is no information, however, on interannual variability in other fish species that contribute to the diverse fish assemblage, energy flow and food chain contribution to the Western Port Ramsar character.	There has been no multi-year study to document interannual variability (i.e. 'natural variability') in assemblages on fish species not of economic importance. It is recommended that if possible, broad-scale sampling should be conducted over two years so that interannual variability ('natural variation') can be estimated.
What were the characteristics of the Western Port fish fauna in 1982?	Information is available on fish primarily from unvegetated and shallow seagrass habitats from the	The existing information on fish assemblages relevant to the 1982 Ramsar baseline needs to be

Key Question	Existing information	Information requirements
	Western Port Environmental studies in the mid 1970s and also the studies by Edgar in the early 1980s. The only information in the area of potential impact of the project is from the studies by Robertson (1978) in the Crib Point area. Information about fish fauna at the 1982 Ramsar baseline is lacking for many habitats (algae, mangrove, reef, seagrass *Amphibolis*), as well as deeper, subtidal seagrass *Zostera* habitat.	collated in a form where it can be used for analyses of change over the intervening time period.
How has the fish fauna changed from the 1982 baseline to the present?	The only information available is for commercial fishing species where catch and effort data is available up until 2007.	Sites sampled for fish around the time of the 1982 Ramsar baseline need to be re-sampled to determine the change that has already occurred in from the baseline prior to the commencement of the project. In particular, re-sampling the site sampled by Robertson (1978) at Crib Point would be a priority because it is in the area of potential impact of the project.
What is an acceptable baseline for the impact assessment?	Limits of acceptable change have not been set for fish species due to lack of access to published information (Kellogg Brown & Root 2010).	Review of existing information and field studies will be used to inform an appropriate baseline.

3.3 Conclusions from review of previous studies and gap analysis

A range of studies have been carried out on fish in Western Port over the past 40 years, however, there are some significant information gaps in relation to the design of the proposed port development in Hastings.

In terms of the spatial coverage of sampling, most sampling sites in previous studies were outside the potential impact area of the project. In particular, there is little information on fish populations and habitat relationships in the area between Hastings and Yaringa where the primary footprint of the project and the major area for potential capital dredging is to occur. This area has a large, shallow gradient *Zostera* seagrass bed that has only been sampled on one occasion previously, and the importance and uniqueness of this seagrass bed to fish populations relative to other locations in Western Port is unknown. Similarly, there has been no previous sampling of fish in the extensive subtidal seagrass beds on the eastern side of the Lower North Arm associated with Middle Spit that are likely to be affected by turbidity plumes.

Previous studies have also mostly focussed on shallow habitats (intertidal and shallow subtidal), when potential impacts of the development, such as reduction of light through increased turbidity from dredging, will most affect deeper subtidal plant habitats, particularly for *Zostera* seagrass. The area between Hastings and Yaringa has a large expanse of subtidal *Zostera* habitat ranging down to 5 m depth. As mentioned, this deeper seagrass has only been sampled on one previous occasion. Deeper subtidal seagrass beds associated with Middle Spit have not been sampled. Moreover, thresholds of habitat loss affecting fish are difficult to determine from previous studies because habitat characteristics (seagrass density etc.) have not been quantified.

Seasonal studies that could inform the timing of project works to mitigate potential impacts on biological processes (e.g. reproduction, migration, recruitment) of important species have been undertaken but only for mangroves and intertidal unvegetated and seagrass habitat in the potential impact area of the project. Seasonal sampling of vulnerable deeper seagrass habitat, that may show different patterns to intertidal habitat, has not been undertaken and would be desirable. Data on interannual variation (i.e. 'natural variation') is only available for important commercial and recreational species based on catch rate data, and information on other species is lacking for any location in Western Port.

In terms of impact pathways and the potential responses of fish, there is almost no information from previous studies in Western Port. In particular, the direct effects of suspended sediments and turbidity are not known for fish in Western Port and are poorly known from elsewhere.

In relation to the Ramsar baseline of 1982 for fish assemblages, the only information on change that has occurred in the intervening years is for commercial fish species. For the non-commercial species that are considered a critical ecosystem component under Ramsar, there is a strong need to re-sample sites that were sampled around that time to determine the level of change that has already occurred in fish assemblages prior to the commencement of the Project.

4. Proposed study methods

The proposed study will focus on seasonal sampling of deeper *Zostera* seagrass habitat in the potential impact area of the project as well as a reference area outside the potential impact zone. The proposed study will also focus on improving understanding of direct effects of suspended sediments and turbidity through field surveys and laboratory experiments.

4.1 Existing conditions field work

4.1.1 Study sites and sampling frequency

Four study sites with deeper, subtidal *Zostera* seagrass habitat will be sampled, two in the Lower North Arm, one in the confluence zone and one in the Rhyll segment.

One site in the Lower North Arm will be located to the north of Hastings between Blue-scope Steel and Yaringa, where the subtidal seagrass is in an extensive bed that grades from the lower intertidal to approximately 4 - 5 m subtidal depth (Figure 1). The development footprint is likely to occur on the southern portion of this bed and the entire bed will be exposed to suspended and settled sediments from capital dredging. This bed has only been sampled previously on one occasion (Jenkins *et al* 2013). This site coincides with seagrass survey work and water quality sampling. Co-location of sampling provides increased data for development of performance requirements.

A second subtidal seagrass site in the Lower North Arm will be sampled near the southern tip of Middle Spit, opposite Stony Point on the French Island side of the lower North Arm (Figure 1). This is a large area of subtidal seagrass that may potentially be affected by turbidity plumes from the development. Again, this site coincides with seagrass survey work and water quality sampling.

Additionally, two subtidal seagrass reference sites would be sampled that will provide information on the spatial variation in fish communities associated with deeper communities and the uniqueness or otherwise of the communities in the Lower North Arm. These sites will be at Tortoise Head, French Island and at Rhyll on Phillip Island (Figure 1).

In terms of documenting the change in fish assemblages since the Ramsar listing in 1982, the site sampled by Robertson (1978) at Woolleys Beach, Crib Point would be re-sampled (Figure 1). Both seagrass and unvegetated mud habitat in lower intertidal/shallow subtidal zone will be sampled. This area is adjacent to the Crib Point development zone and seagrass in this area could potentially be affected by the turbidity plume from the dredging work associated with the Project.

Sampling of each site will be conducted once each season over one year so that seasonal changes in the fish assemblages can be documented, including key life history processes (e.g. reproduction, migration, recruitment) of important species, potentially informing the project design in terms of the timing of events such as capital dredging. Extending the study into a second year would provide valuable information on interannual variability and their background natural variation that would inform limits of acceptable change in relation to the Ramsar listing.

4.1.2 Field and laboratory methods

Sampling of deeper subtidal seagrass habitats will be undertaken with a mini otter trawl (Jenkins *et al*. 2013) at subtidal depths of 1 to 5 metres. The mini otter trawl has a 3.9 metre head rope that is kept open using small trawl doors (Figure 2). A 5 mm mesh liner in the main net and 3 mm mesh liner in the cod-end will retain small species and recruits of larger species, as well as older and larger specimens. The mini otter trawl can be used effectively from a small research vessel. Four to six, haphazardly placed hauls will be undertaken at each location on each sampling date. Each haul will consist of a 5 minute tow (from the time the warps are fully deployed until the start of retrieval) at a speed of 1-1.2 knots (covering a distance of approximately 150 -200 m). A live-view video drop camera will be used at the start of each tow to confirm the habitat being sampled.

Sampling of intertidal and shallow subtidal habitats at Crib Point will be undertaken with a seine net (Hutchinson et al. 2014). This net is 10 m long and 2 m deep with a 1 mm mesh, and has a 10 m hauling rope attached to each end (Figure 3). To set the net the boat is anchored and then a researcher walks the net out and then returns to the boat for retrieval. Four to six, haphazardly placed hauls will be undertaken in each habitat (seagrass and unvegetated mud) on each sampling date.

Where possible fish will be identified and measured (total length) immediately after capture and released alive. Where more than 30 individuals of a species are collected in a haul, a random subsample of 30 individuals will be measured. Difficult to identify species will be anaesthetised in clove oil solution and preserved in 95% ethanol and returned to the laboratory for identification and measurement. In the laboratory, fish will be identified with reference to Gomon *et al.* (2008), counted, and measured to the nearest mm (total length).

At the end of each haul, physico-chemical measurements, including temperature, salinity, dissolved oxygen and turbidity will be measured vertically through the water column at 1 metre intervals with a Hydrolab Sonde.

4.1.3 Data Analysis

A two-factor ANOVA with Site and Season as main effects will be used to analyse the mini otter trawl data, and Habitat and Season as main effects for the seine net data. Dependent variables in the analyses will be species richness, total abundance and abundance of key species. Data will be checked for homogeneity of variance and normality and transformed where necessary to meet the assumptions of the analysis (Quinn and Keough 2002). Where effects are significant, Tukey's HSD post-hoc test will be used to make pairwise comparisons. Frequency distributions of fish length will be compared amongst Sites and Seasons using the Kolmogorov Smirnov two-sample test.

A multivariate analogue of ANOVA, Analysis of Similarities (AMOSIM) (Clarke 1993; Clarke and Gorley 2006) will be used to make comparisons of Sites and Seasons (trawl) and Habitat and Seasons (Seine) for data at the assemblage level. The analysis will be based on Bray Curtis dissimilarity matrices (Clarke 1993; Clarke and Gorley 2006). The data will be initially log(x+1) transformed to reduce the influence of species with high abundance. Relationships will also visualised with non-metric multidimensional scaling (nMDS) ordinations (Clarke 1993; Clarke and Gorley 2006). A SIMPER procedure will then be used to identify the species that contributed most to differences in fish assemblages (Clarke 1993; Clarke and Gorley 2006).

4.2 Measurement of fish responses to the direct impact of turbidity ad suspended sediments

The stressor turbidity (total suspended solids) can affect fish by clogging gills (affecting physiology/respiration) and reducing visibility (influencing feeding and migratory behaviour). A transect will be established in the Upper North Arm along a strong turbidity gradient (increasing from west to east) to examine ecological responses of fish to turbidity and increased TSS (Figure 1). Samples will be taken at eight points along the turbidity transect with the mini otter trawl using the methods described above. Sampling will be on unvegetated mud/sand habitat in approximately 2 – 5 m subtidal depth. Unvegetated habitat was selected because vegetated habitat (e.g. seagrass) would be likely to also be affected by the turbidity gradient and therefore would confound the results for fish. Physico-chemical measurements will also be taken at the conclusion of each net haul as described above. The transect will be sampled on a seasonal basis to improve the generality of results. The data analysis will be as described above but would also include multiple regression analysis of environmental variables, including turbidity, as predictor variables for fish ecological variables such as species richness, total abundance and abundance of key species along the turbidity/TSS gradient.

There is also potential to undertake laboratory experiments on the effects of turbidity/TSS on key fish species. This can be undertaken by project staff or could potentially from part of a Master of Science research project. A system of replicated flow-through aquaria (100 L) at the Victorian Marine Science Consortium laboratories in Queenscliff will be used to conduct experiments using multiple treatment levels of turbidity/TSS. Treatment levels will range from control (zero turbidity/TSS) to levels that could potentially occur as a result of the project. Key fish groups will be examined for differences in feeding rate and behaviour, growth and survival based on treatment levels will be measured over intervals of one two and three months. Habitat will be provided in the aquaria in the form of artificial seagrass and food will be provided in the form of cultured copepods. As an example, pipefishes (Syngnathidae) are a key group of ecological and conservation concern that could be examined in these experiments. Responses of juveniles of important fishing species such as King George whiting will also be examined in these experiments. The results of the experiment will provide the only available information on responses of key local species of fish to turbidity/TSS. The results will reduce uncertainty in our estimates of fish response, which will be assayed against modelled and measured levels of turbidity/TSS in the environment. The results will increase the certainty of project impact assessment, reducing the probability of overly conservative outcomes.

These studies will contribute to refining the ecological response curves of fish to turbidity effects that were developed using literature effects on different locations and species. The work will provide increased confidence that the ecological response of fish to suspended sediments is understood in relation the Western Port marine environment.

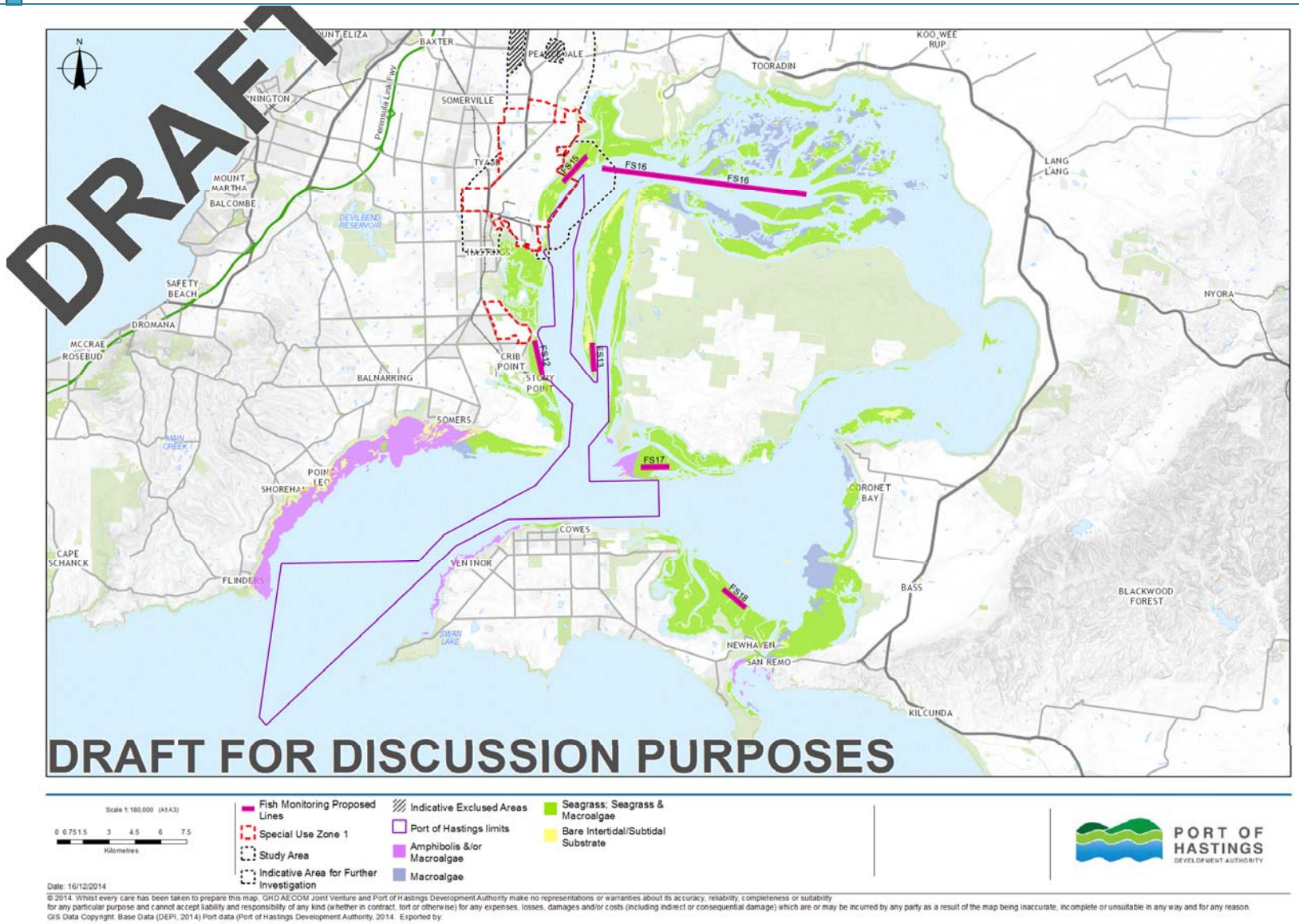

Figure 2. Proposed fish monitoring sites and proposed fish/turbidity transect.

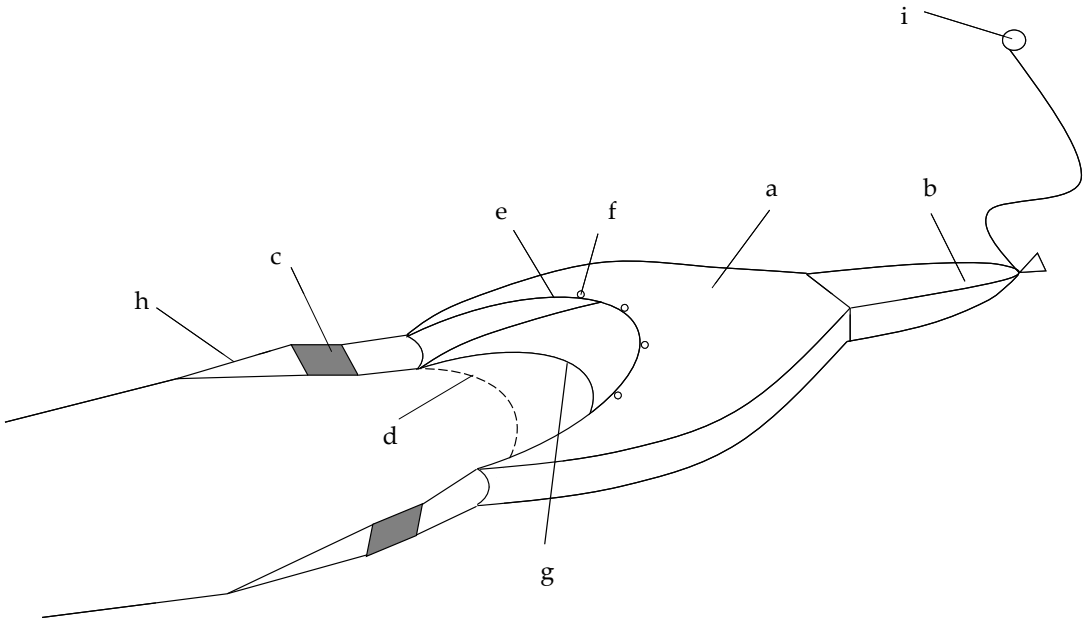

Figure 3. Diagram of mini otter trawl net employed to sample in Western Port, a) main body of net and liner (net – 38.1 mm aperture knotted nylon; liner - 5 mm aperture knotted nylon); b) codend bag of net and liner (net – 31.75 mm aperture knotted nylon; liner – 3 mm aperture knotless nylon); c) wooden otter-boards – 61 cm x 31 cm weighted with lead sheets; d) tickler chain; e) head rope – 390 cm; f) 4 foam floats; g) foot rope and chain (390 cm); h) bridle ropes; i) alternate retrieval line.

Figure 4. Seine net operating on seagrass.

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